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CLINICAL INVESTIGATION

# Long-Term Outcomes of Patients with Lumbar Disc Herniation Treated with Percutaneous Discectomy: Comparative Study with Microendoscopic Discectomy

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**Abstract** We assessed the long-term outcomes of patients with lumbar disc herniation treated with percutaneous lumbar discectomy (PLD) or microendoscopic discectomy (MED). A retrospective study was performed in consecutive patients with lumbar disc herniation treated with PLD ($n = 129$) or MED ($n = 101$) in a single hospital from January 2000 to March 2002. All patients were followed up with MacNab criteria and self-evaluation questionnaires comprising the Oswestry Disability Index and Medical Outcomes Study 36-Item Short-Form Health Survey. Several statistical methods were used for analyses of the data, and a $p$ value of $<0.05$ was considered to be statistically significant. A total of 104 patients (80.62%) with PLD and 82 patients (81.19%) with MED were eligible for analyses, with a mean follow-up period of $6.64 \pm 0.67$ years and $6.42 \pm 0.51$ years, respectively. There were no significant differences between the two groups in age, number of lesions, major symptoms and physical signs, and radiological findings. According to the MacNab criteria, 75.96% in the PLD group and 84.15% in the MED group achieved excellent or good results, respectively, this was statistically significant ($p = 0.0402$). With the Oswestry Disability Index questionnaires, the average scores and minimal disability, respectively, were 6.97 and 71.15% in the PLD group and 4.89 and 79.27% in the MED group. Total average scores of Medical Outcomes Study 36-Item Short-Form Health Survey were 75.88 vs. 81.86 in PLD group vs. MED group ($p = 0.0582$). The cost and length of hospitalization were higher or longer in MED group, a statistically significant difference (both $p < 0.0001$). Long-term complications were observed in two patients (2.44%) in the MED group, no such complications were observed in the PLD group. Both PLD and MED show an acceptable long-term efficacy for treatment of lumbar disc herniation. Compared with MED patients, long-term satisfaction is slightly lower in the PLD patients; complications, hospitalization duration, and costs in PLD group are also lower.

**Keywords** Lumbar disc · Herniation · Discectomy · Percutaneous · Microendoscopic · Follow-up · Long-term outcomes · Quality of life

## Introduction

Over the past 40 years, minimally invasive treatment for lumbar disc herniation has increasingly used by surgeons and interventionalists. As a result, a number of percutaneous intradiscal therapies have evolved, which include chemonucleolysis, manual percutaneous nucleotomy, laser decompression, intradiscal thermal annuloplasty, nucleoplasty and chemodiscolysis with an oxygen–ozone mixture. However, there are few studies on the comparison of the various minimally invasive therapies [1–7], and to our knowledge, there has been no investigation on the long-term (more than 5 years) outcomes related to the different techniques.

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In our hospital, we have performed more than 4000 percutaneous lumbar discectomies (PLD) on patients in the Department of Interventional Radiology and over 1600 microendoscopic discectomies (MED) on patients in the Department of Orthopedic Surgery before 2007. As in other reports [8–16], we have achieved favorable short-term and midterm outcomes with these two methods [17, 18]. The purpose of this study was to retrospectively compare the long-term (more than 5 years) outcomes in patients with lumbar disc herniation treated with PLD or MED.

## Materials and Methods

### Data Collection

The study protocol was approved by our institutional ethics committee. The data of the consecutive hospitalized patients with lumbar disc herniation treated with PLD or MED in our single hospital during January 2000 to March 2002 were retrospectively collected. The demographic characteristics of the patients, including age, sex, duration of lower back pain, neurological deficit, and radiological examinations, were collected by an independent physician (W.G.L.) who was not a member of either interventional or orthopedic group at the time of the PLD or MED procedures included in this study. The outcomes of MacNab's response and quality-of-life measures (Oswestry Disability Index [ODI] and Medical Outcomes Study 36-Item Short-Form Health Survey [SF-36]) were sent via postal mail and followed by phone interviews.

### Inclusion and Exclusion Criteria

The same inclusion and exclusion criteria were defined in both groups. The inclusion criteria were as follows: (1) neurological signs including radiculopathy, sensory changes, motor weakness, and the presence of abnormal reflex due to migrated disc; (2) contained disc protrusion on preoperative magnetic resonance imaging and/or computed tomographic scans; (3) unsuccessful conservative treatment for at least 6 weeks; (4) age of 16–70 years at time of procedure; and (5) no previous lumbar surgery on the same disc level. Exclusion criteria were as follows: (1) central spinal canal stenosis or lateral recess stenosis; (2) a narrowing foramen; (3) sequestered disc below or above the center of the pedicle of the lower vertebral body; (4) coexisting somatic or psychological condition, such as cardiovascular diseases, diabetes, infection, spinal tumor, or fracture; and (5) patient unreachable because of lack of corresponding address.

A total of 129 PLD patients (84 men and 45 women) and 101 MED patients (67 men and 34 women) met the above criteria among 465 total patients who underwent PLD ($n = 278$) or MED ($n = 187$) during this period.

### Procedures

The PLD procedure was performed by interventional radiologists under a C-arm X-ray machine with Teng's automated percutaneous discectomy [17]. A posterolateral approach of puncture was carried out with a puncture entry point approximately 8–12 cm from the midline of the spine column with the patient under local anesthesia and in the lateral decubitus position. First, an 18-gauge trocar needle with a removable hub was placed into the center of the disc with the confirmation of biplane fluoroscopy. Serial coaxial dilators becoming gradually larger were passed over the first hubless needle. Finally, a 3.5-mm cannula was advanced into the center of the disc. After the position was confirmed, the automated discectomy ran for 15–20 min for suction of the nucleus pulposus. The patient was sent back to the ward and observed for at least 3 days before discharge.

The MED procedure [18] was performed by orthopedists. Under epidural anesthesia, the patient was placed in a prone position. Under X-ray control, a spinal needle was placed paramedial to the side of disc herniation; subsequently, a 16-mm incision was made, and a K wire was placed under X-ray control at the offending disc level parallel to the disc space. Serial dilators were then passed over this. Finally, an operating post 16 mm in diameter was placed. The endoscope was then brought in and fixed to this port with an adapter. The laminae, facet, and ligamentum flavum were identified. Laminotomy and medial facetectomy were performed. Removal of ligamentum flavum and annulotomy was performed with a microknife, if indicated, and the herniated disc was removed with a pituitary rongeur in the standard fashion. The nerve root was examined to ensure the decompression was complete.

### Outcome Assessment

MacNab criteria and the Chinese version of self-evaluation questionnaires of the ODI and SF-36 were used for the outcome assessment. The assessments also included recurrence of symptoms, complications, subsequent surgical therapy, hospitalization duration, and costs, all of which were reviewed by phone and initial records of all the patients. In our study, we only assess the direct medical costs, which included the costs of diagnosis, surgery, medication, and treatment due to complications during hospitalization.

The follow-up was terminated 4 months after the letter mailed. Patient status immediately before the surgical treatment was evaluated in those who underwent subsequent open surgery due to failed PLD or MED.

*MacNab Criteria*

The MacNab criteria defined excellent outcome as no pain and no limitation of normal life; good outcome as occasional pain or paresthesia, but no need of medication and no limitation of normal life; fair outcome as somewhat improved pain and a need for medication, with some limitation of normal life; and poor outcome as no improvement or worsening, and/or a need for additional surgical treatment due to incomplete decompression.

*Oswestry Disability Index*

The ODI is divided into 10 items designed to assess multiple aspects of disability with respect to pain: pain, personal care, lifting, walking, sitting, standing, sleeping, sex life, social life, and traveling. Each ODI item is scored on a 0 to 5 scale, with 5 representing the greatest level of disability. The scores for all items are then summed to give a score out of 50. A lower score indicates less severe symptoms. The total score is then doubled and expressed as a percentage and graded into severe disability (ODI $> 40\%$) and minimal disability (ODI $< 20\%$). The sex-life question in the translated Chinese ODI was omitted for cultural reasons; therefore, the total score became 45.

*Medical Outcomes Study 36-Item Short-Form Health Survey*

The SF-36 health survey questionnaire is typically used for the assessment of health-related quality of life. It can easily be filled out at home. The questionnaire consists of 36 items on physical and social status of the patient subdivided in eight domains: (1) PF, physical functioning; (2) RP, role limitations due to physical health; (3) RE, role limitations due to emotional problems; (4) VT, energy/fatigue; (5) MH, emotional well-being; (6) SF, social functioning; (7) BP, body pain; and (8) GH, general health. The questions are scored on a scale of 0 (worst health) to 100 (ideal health).

Statistical Analysis

Data were compiled in a Microsoft Excel database, and analysis was performed by SPSS for Windows version 12.0 (SPSS, Chicago, IL). Comparison between subgroups was made with paired-sample *t*-tests, $\chi^2$ tests, Fisher's exact tests, and analysis of variance. Statistical significance was accepted at $p < 0.05$.

## Results

Patients' Demographic Information

The mean follow-up period was $6.64 \pm 0.67$ years in PLD group and $6.42 \pm 0.51$ years in MED group. A total of 104 PLD patients (80.62%) had data available for analyses; data from 82 patients (81.19%) with MED were available. Among the 25 excluded patents with PLD, loss of follow-up due to moving house or to our having the wrong address or incorrect contact information occurred in 21 patients. Accompanying disease were present in three patients (rheumarthritis in two and heart infarction in one), which could influence their quality of life, and one patient died from drug abuse. Among the 19 excluded patients in MED group, loss of follow-up occurred in 15 patients. The remaining were invalid questionnaire forms; they were the result of illiteracy in one patient, accompanying disease in two patients (arthritis in one and vertebral arch fracture in one), and death from stroke in one patient.

The preoperative demographic information and descriptive data of the participants are shown in Table 1. Only the item "disc levels treated" showed statistical significance.

*MacNab Criteria*

According to the MacNab criteria, 31 patients (29.81%) had excellent results, 48 (46.15%) good results, and 25 (24.04%) fair or poor results in the PLD group, while in the MED group, 39 patients (47.56%) had excellent results, 30 (36.59%) good results, and 13 (15.85%) fair or poor results. Excellent and good results were 75.96% and 84.15% in PLD group and MED group, respectively, which is statistically significant ($p = 0.0402$).

*Oswestry Disability Index*

The pretreatment ODI scores and scores at the follow-up at 6.64 vs. 6.42 years after treatment with the PLD or MED are shown in Table 2. Although the scores between two groups before the treatment were similar ($p = 0.789$, rank sum test), the scores after treatment in the MED group were better than that in the PLD group ($p = 0.040$, rank sum test). In the PLD group, severe disability (ODI $> 40\%$) of long-term follow-up was classified in 14 patients (13.46%), minimal disability (ODI $< 20\%$) in 74 patients (71.15%), and no disability (ODI $= 0$) in 18 patients (17.31%), which corresponded to 5 patients

**Table 1** Baseline demographic information of patients before treatment

| Item | PLD | MED | *p* value |
|---|---|---|---|
| Age (year) | | | 0.8699 |
| Mean ± SD | 42.86 ± 10.57 | 42.09 ± 10.15 | |
| Range | 16–70 | 17–69 | |
| Sex (*n* ) | | | 0.0684 |
| Male | 73 | 47 | |
| Female | 31 | 35 | |
| Duration of lower back pain (*n* ) | | | 0.3597 |
| ≤3 month | 25 | 17 | |
| 3 month to 3 year | 44 | 48 | |
| ≥3 year | 35 | 17 | |
| Calcification of the posterior longitudinal ligament (*n* ) | 4 | 4 | 0.7330 |
| Calcification of the disc (*n* ) | 3 | 3 | 1.000 |
| Straight-leg raising test (*n* ) | | | 0.0743 |
| ≤40 degrees | 26 | 19 | |
| 40–70 degrees | 46 | 54 | |
| ≥70 degrees | 32 | 9 | |
| Disc levels treated (*n* ) | | | <0.0001 |
| L2/3L5S1 | 1 | 0 | |
| L3/4 | 1 | 1 | |
| L3/4L4/5 | 6 | 0 | |
| L4/5 | 63 | 31 | |
| L4/5L5S1 | 12 | 4 | |
| L5S1 | 21 | 46 | |
| Follow-up duration (year) (mean ± SD) | 6.64 ± 0.67 | 6.42 ± 0.51 | 0.3381 |

*PLD* percutaneous lumbar discectomy, *MED* microendoscopic discectomy

**Table 2** ODI scores of patients in the PLD and MED groups

| Group | ODI score | | | | | Average score | <20% (0–8) |
|---|---|---|---|---|---|---|---|
| | 0 | 1–8 | 9–17 | 18–26 | >26 | | |
| PLD group | | | | | | | |
| Before treatment[a] | 0 | 0 | 4 | 57 | 43 | 25.75 ± 5.57 | 0 |
| After treatment[b] | 18 | 56 | 14 | 14 | 2 | 6.97 ± 7.68 | 74 (71.15%) |
| MED group | | | | | | | |
| Before treatment | 0 | 0 | 2 | 44 | 36 | 25.50 ± 5.59 | 0 |
| After treatment | 21 | 44 | 12 | 2 | 3 | 4.89 ± 6.50 | 65 (79.27%) |

*ODI* Oswestry Disability Index, *PLD* percutaneous lumbar discectomy, *MED* microendoscopic discectomy

[a] Pretreatment scores between the groups: $Z = -0.268$, $p = 0.789$, rank sum test

[b] Posttreatment scores between the groups: $Z = -2.051$, $p = 0.040$, rank sum test

(6.10%), 65 patients (79.27%), and 21 patients (25.61%), respectively, in the MED group.

*Short Form-36 (SF-36)*

In comparing the SF-36 scores of the PLD group with the MED group (Table 3), although the total average scores did not reach a statistical significant threshold ($p = 0.0582$), the domains of SF (social functioning) and BP (body pain) in the MED group were significantly better than that in PLD group ($p = 0.0080$ and $p = 0.0039$, respectively).

Complications and Subsequent Surgical Therapy

No complications occurred in the PLD group, while in the MED group, there was one case of muscle cramping and decreased sexual function and one case of muscular

**Table 3** SF-36 scores of patients in the PLD and MED groups[a]

| Group | Domain | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | PF | RP | RE | VT | MH | SF | BP | GH | |
| PLD | 79 | 68 | 74 | 76 | 80 | 80 | 76 | 74 | 75.88 |
| MED | 86 | 77.7 | 81.2 | 78 | 81 | 89 | 84 | 78 | 81.86 |

*SF-36* Medical Outcomes Study 36-Item Short-Form Health Survey, *PLD* percutaneous lumbar discectomy, *MED* microendoscopic discectomy, *PF* physical functioning, *RP* role limitations due to physical health, *RE* role limitations due to emotional problems, *VT* energy/fatigue, *MH* emotional well-being, *SF* social functioning, *BP* body pain, *GH* general health

[a] The $\chi^2$ test was used for statistical examinations in all domains and total scores between two groups. RF: $\chi^2 = 3.3834$, $p = 0.0659$; RP: $\chi^2 = 2.4942$, $p = 0.1143$; RE: $\chi^2 = 2.3125$, $p = 0.1283$; VT: $\chi^2 = 0.4263$, $p = 0.5138$; MH: $\chi^2 = 0.1215$, $p = 0.7275$; SF: $\chi^2 = 7.0407$, $p = 0.0080$; BP: $\chi^2 = 8.3324$, $p = 0.0039$; GH: $\chi^2 = 2.4558$, $p = 0.1171$; total scores: $\chi^2 = 3.5887$, $p = 0.0582$

atrophy in the leg (data found in patients' further consultation records). Open surgical discectomy was subsequently carried out in eight patients (7.69%) in the PLD group and two patients (2.44%) in the MED group who did not respond to the minimally invasive treatment.

### Economic Assessment and Hospitalization Duration

In comparing the average hospital stay and the average cost of the PLD with MED groups (Table 4), there was significantly shorter duration of hospitalization and lower cost in the PLD group (both $p < 0.0001$).

## Discussion

Chronic lower back pain is one of the most frequent health problems in industrialized societies [19]. Approximately 80% of the population in Western countries have experienced at least one episode of lower back pain in their lifetime, and 55% experienced lower back pain associated with radicular syndromes [20]. The spine is a major source of pain and disability [21]. The intervertebral disc, because of its highly specialized role and relatively susceptible nature, is one of the major sources of lower back pain syndrome. This injury can be accompanied by intense pain around the affected disc as well as pain that radiates to the lower back and legs.

**Table 4** Average duration of hospitalization and costs in PLD and MED groups

| Group | Average hospital stay[a] | Average cost[b] |
|---|---|---|
| PLD | 7.90 days | ¥4548 |
| MED | 11.59 days | ¥5994 |

*PLD* percutaneous lumbar discectomy, *MED* microendoscopic discectomy

[a] Analysis of variance, $F = 84.20$, $p < 0.0001$

[b] Analysis of variance, $F = 34.63$, $p < 0.0001$

PLD was first described by Hijikata et al. in 1975. It was modified to automated PLD (APLD) by Onik et al., which was based on the principle that in an enclosed space, a reduction in volume, even a partial one, confers a great reduction in pressure [8–10]. The American Academy of Orthopedic Surgeons has listed percutaneous discectomy as an accepted procedure for the treatment of herniated lumbar discs [10]. We reported a prospective study in 10 independent hospitals' 1525 patients from 1992 to 1994 evaluated APLD with a newly designed Teng's percutaneous instrument and achieved a good result of 83% at 1 year [17].

Poor results are reported in four randomized trials on APLD: Revel et al. [4] and Krugluger and Knahr [5] performed randomized trials of APLD and chemonucleolysis, whereas Chatterjee et al. [6] and Haines et al. [7] performed trials comparing APLD with microdiscectomy. When compared with our study, the limitations of these studies are probably related to, among other factors, the small number of patients, the learning curve of APLD, the various techniques and instruments of APLD used, and different patient selection criteria. The importance of patient selection for this particular technique is acknowledged [8, 22]. Nevertheless, a new systematic review on APLD indicates level 2 evidence for APLD [23], and the authors conclude that APLD may provide appropriate relief in properly selected patients with contained lumbar disc prolapse [23]. However, because there are only four randomized controlled trials in the 80 studies in this systematic review [23], better-quality randomized controlled trials with sufficient power and adequate randomization, use of validated outcome measures, and cost-effectiveness studies are required to define the role of percutaneous discectomy [24, 25].

In 1997 Foley and Smith introduced the transmuscular approach of MED with advanced optics and instruments applied in laparoscopic surgery [12]. This technique is a combination of endoscopy and standard microscopic discectomy by means of a posterior approach similar to that of microdiscectomy. The indications for this procedure are posterolateral disc herniation with or without lateral recess stenosis, and foraminal and extraforaminal disc herniations, which are similar to the indications of PLD. Good to excellent outcomes have been reported in 91–100% of patients undergoing MED [11–15]. We reported 873 consecutive patients with lumbar disc herniation treated by MED and demonstrated a significant improvement of ODI scores after treatment [18].

Although many studies have proven the safety and efficacy of both PLD and MED [3, 8–18], there are few known reports of long-term follow-up results for the two procedures, and almost no studies comparing PLD and MED have been reported in the literature. As we know, the main indications for the two procedures are similar. Our preoperative demographic information (Table 1) has also demonstrated their comparability. Although the item "disc levels treated" shows a statistical significance in the present data, many studies have proven that it is not a factor influencing the results for both PLD and MED [8, 13, 17, 18].

ODI has become one of the principal condition-specific outcome measures used in the management of spinal disorders. It has also been shown to be valid and responsive to changes in clinical status [26–29]. Some studies maintain the ODI as the gold standard outcome measure [28]. The U.S. Food and Drug Administration has chosen a minimum 15-point change in patients who undergo spinal fusion before surgery and at follow-up [26]. In comparing their preoperative self-evaluation scores in this study, the patients' ODI scores with long-term follow-up in both PLD and MED groups showed significant improvement (Table 2).

The SF-36 health assessment questionnaire has been proven to be a valuable instrument. It has been used in over a thousand publications and is available in a dozen translations. There have been many authors who have implemented it in the assessment of patients with lower back pain [29–36]. The advantage of this questionnaire is that the SF-36 achieves the best balance between length, reliability, validity, responsiveness, and experience even in large populations of patients who experience lower back pain [29, 30]. In our data in Table 3, the total average scores were very close to the statistical significant threshold ($p = 0.0582$), and the domains of social functioning and body pain in the MED group were significantly better than that in the PLD group (both $p < 0.01$).

In our data, various degrees of impact were demonstrated in different domains. Although several patients had ODI scores of >10, they felt happy compared with their pretreatment status of "only lying in bed," while few patients insisted that their quality of life was unsatisfactory no matter the ODI score of 0, which may be because of economic or other factors such as unexpected high costs. These findings are similar to those of other studies that showed that various factors influence quality of life, including age, medical and psychiatric comorbidity, psychological distress, long duration of sick leave, long history of back pain, short preoperative walking distance, and reduced social activities [32–34].

The MacNab criteria [37] comprise one of the most important instruments for the assessment of patients with lower back pain. In our study, the excellent and good results of 75.96% and 84.15% in the PLD and MED groups are obtained at a follow-up of 6.64 and 6.42 years, respectively, which is similar to our own previously reported studies [17, 18] with a shorter follow-up of a mean of 18.3 months and 28 months, respectively.

In our study, 10 patients underwent subsequent open surgery in different durations after PLD (eight patients) or MED (two patients), which was lower than in other studies with PLD [8, 38]. One of the causes for the lower instances of surgery after PLD is probably related to our modifications of the technique and instruments of PLD, our patient selection criteria, and our familiarity with the operation, as well as other related factors [17]. Other aspects might be that in our study, some patients without relief of the symptoms after PLD (Table 2) did not agree to subsequent treatment for economic or psychological reasons. Thus, the number of patients in need of surgery exceeded the number who actually underwent surgery.

There are several limitations to this study. First, the follow-up rate in the both groups was low, which may be mostly due to the changes of their address—many new apartments and houses have been constructed, and almost all Chinese urban citizens have changed their addresses at least once during the past 10 years. Second, no long-term radiological examinations were provided in this study. Patients with good results usually refuse to come back for radiological examinations, while the patients with poor results have to be examined, which would bias the data. Third, in the present study, the number of patients might be too small to correlate the long-term outcomes of the two procedures with the influenced factors such as calcification of the posterior longitudinal ligament or disc, degree of disc herniation, and history of duration before treatment.

Both PLD and MED show satisfactory long-term efficacy and safety for the treatment of lumbar disc herniation. Although the long-term satisfaction rating in the MED group is slightly higher than that in the PLD group, the complications, duration of hospitalization, and costs are higher than that of the PLD group.

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## References

1. Lee SH, Chung SE, Yong A et al (2006) Comparative radiologic evaluation of percutaneous endoscopic lumbar discectomy and open microdiscectomy: a matched cohort analysis. Mt Sinai J Med 73:795–801
2. Tassi GP (2006) Comparison of results of 500 microdiscectomies and 500 percutaneous laser disc decompression procedures for lumbar disc herniation. Photomed Laser Surg 24:694–697

3. Schizas C, Tsiridis E, Saksena J (2005) Microendoscopic discectomy compared with standard microsurgical discectomy for treatment of uncontained or large contained disc herniations. Neurosurgery 57:357–360
4. Revel M, Payan C, Vallee C et al (1993) Automated percutaneous lumbar discectomy versus chemonucleolysis in the treatment of sciatica. A randomized multicenter trial. Spine 18:1–7
5. Krugluger J, Knahr K (2000) Chemonucleolysis and automated percutaneous discectomy—a prospective randomized comparison. Int Orthop 24:167–169
6. Chatterjee S, Foy PM, Findlay GF (1995) Report of a controlled clinical trial comparing automated percutaneous lumbar discectomy and microdiscectomy in the treatment of contained lumbar disc herniation. Spine 20:734–738
7. Haines SJ, Jordan N, Boen JR et al (2002) LAPDOG/LEAPDOG Investigators. Discectomy strategies for lumbar disc herniation: results of the LAPDOG trial. J Clin Neurosci 9:411–417
8. Bonaldi G (2003) Automated percutaneous lumbar discectomy: technique, indications and clinical follow-up in over 1000 patients. J Neuroradiol 45:735–743
9. Cosma A, Mario M, Marco L (2004) Interventional spinal procedures. Eur J Radiol 50:112–119
10. Onik G, Clyde A, Helms CA (1991) Automated percutaneous lumbar diskectomy. AJR Am J Roentgenol 156:531–538
11. Degobbis A, Crucil M, Alberti M, Bortolussi A (2005) A long-term review of 50 patients out of 506 treated with automated percutaneous nucleotomy according to Onik for lumbar-sacral disc herniation. Acta Neurochir 92:103–105
12. Foley KT, Smith MM (1997) Microendoscopic discectomy. Techn Neurosurg 3:301–307
13. Alok R, Rahul L (2006) Microendoscopic discectomy for prolapsed lumbar intervertebral disc. Neurol India 54:190–194
14. Foley KT, Smith MM, Rampersaud YR (1999) Microendoscopic approach to far lateral lumbar disc herniation. Neurosurg Focus 7:5
15. Chang SS, Fu TS, Liang YC et al (2009) Results of microendoscopic discectomy performed in the 26 cases with a minimum 3 years follow-up. Chang Gung Med J 32:89–97
16. Rong LM, Xie PG, Shi DH et al (2008) Spinal surgeons' learning curve for lumbar microendoscopic discectomy: a prospective study of our first 50 and latest 10 cases. Chin Med J 121:2148–2151
17. Teng GJ, Jeffery RF, Guo JH et al (1997) Automated percutaneous lumbar discectomy: a prospective multi-institutional study. J Vasc Interv Radiol 8:457–463
18. Wu XT, Zhuang SY, Mao Z et al (2006) Microendoscopic discectomy for lumbar disc herniation: surgical technique and outcome in 873 consecutive cases. Spine 31:2689–2694
19. Luo X, Pietrobon R, Sun SX et al (2004) Estimates and patterns of direct health care expenditures among individuals with back pain in the United States. Spine 29:79–86
20. Long MD (1991) Decision making in lumbar disc disease. Clin Neurosurg 39:36–51
21. Olmarker K, Rydebik B (1991) Pathophysiology of sciatica. Orthop Clin North Am 22:223–234
22. Mark V, Andrea M, Sukdeb D et al (2007) Interventional techniques: evidence-based practice guidelines in the management of chronic spinal pain. Pain Physician 10:7–111
23. Hirsch JA, Singh V, Falco FJE et al (2009) Automated percutaneous lumbar discectomy for the contained herniated lumbar disc: a systematic assessment of evidence. Pain Physician 12:601–620
24. Brian JC (2008) Intradiscal electrothermal therapy, percutaneous discectomy, and nucleoplasty: what is the current evidence? Curr Pain Headache Rep 12:14–21
25. Maurits W, Bart K, Seppo S et al (2006) Outcome of invasive treatment modalities on back pain and sciatica: an evidence-based review. Eur Spine J 15:S82–S92
26. Fairbank JC, Pynsent PB (2000) The Oswestry Disability Index. Spine 25:2940–2953
27. Roland M, Fairbank J (2000) The Roland-Morris Disability Questionnaire and the Oswestry Disability Questionnaire. Spine 25:3115–3124
28. Hideki H, Magahi K, Osamu N et al (2006) Discriminative validity and responsiveness of the Oswestry Disability Index among Japanese outpatients with lumbar conditions. Eur Spine J 15:1645–1650
29. Fairbank JC, Couper J, Davies JB, O'Brien JP (1980) The Oswestry Low Back Pain Disability Questionnaire. Physiotherapy 66:271–273
30. Zanoli G, Jonsson B, Stromqvist B (2006) SF-36 scores in degenerative lumbar spine disorders: analysis of prospective data from 451 patients. Acta Orthop 77:298–306
31. Stansfeld SA, Roberts R, Foot SP (1997) Assessing the validity of the SF-36 General Health Survey. Qual Life Res 6:217–224
32. Hollingworth W, Deyo RA, Sullivan SD et al (2002) The practicality and validity of directly elicited and SF-36 derived health state preferences in patients with low back pain. Health Econ 11:71–85
33. Kotryna V, Kazys V, Ambrozaitis Bronius Š (2007) Health-related quality-of-life assessment in patients with low back pain using SF-36 questionnaire. Medicina (Kaunas) 43:607–613
34. Dirk H, Katharina K, Margrit Z et al (2007) Health-related quality of life in patients after lumbar disc surgery: a longitudinal observational study. Qual Life Res 16:1453–1460
35. Walsh TL, Hanscom B, Lurie JD et al (2003) Is a condition-specific instrument for patients with low back pain/leg symptoms really necessary? The responsiveness of the Oswestry Disability Index, MODEMS, and the SF-36. Spine 28:607–615
36. Grevitt M, Khazim R, Webb J et al (1997) The short form-36 health survey questionnaire in spine surgery. J Bone Joint Surg Br 79:48–52
37. Macnab I (1971) Negative disc exploration: an analysis of the causes of nerve-root involvement in sixty-eight patients. J Bone Joint Surg Am 53:891–903
38. Bernd L, Schiltenwolf M, Mau H, Schindele S (1997) No indications for percutaneous lumbar discectomy? Int Orthop 21:164–168